Claims

1. A method of forming two level structures in a semiconductor substrate, the method comprising:

forming lines of different widths having a first floor;

oxidizing the wafer until lines of thinner width are substantially fully oxidized;

etching the oxide to expose the first floor; and

etching the exposed first floor deeper into the substrate to form a second floor.

2. The method of claim 1 and further comprising removing the oxide from the lines.

3. The method of claim 2 wherein the oxide is removed using HF etching or CHF_3 reactive ion etching.

4. The method of claim 1 wherein etching the oxide comprises using a CHF_3 anisotropic reactive ion etch.

5. The method of claim 1 wherein the semiconductor substrate is single crystal silicon.

6. The method of claim 1 wherein the first floor is etched deeper using deep reactive ion etching.

7. The method of claim 6 wherein the deep reactive ion etch comprises a CHF_3 reactive ion etch.

8. The method of claim 7 wherein the deep reactive ion etch is performed with CHF_3 flowing at a flow rate of approximately 30 sccm and a pressure of approximately 90 millitorr.

9. The method of claim 1 wherein the wafer is oxidized using thermal oxidation.

10. A method of forming multiple level structures in a semiconductor substrate, the method comprising:

forming structures in the substrate having different widths;

oxidizing the wafer until structures of a desired width are substantially fully oxidized;

etching the oxide to expose a floor of the substrate; and

etching the floor deeper into the substrate to form a next floor.

11. The method of claim 10 and further comprising removing the oxide and repeating oxidizing, etching and etching to form a further level of the multiple level structure, wherein successively wider line widths are oxidized.

12. The method of claim 11 wherein the oxide is removed using CHF_3 reactive ion etching.

13. The method of claim 10 wherein etching the floor of the substrate comprises using a reactive ion etch.

14. The method of claim 13 wherein the reactive ion etch comprises a CHF_3 reactive ion etch.

15. The method of claim 10 wherein the semiconductor substrate is single crystal silicon.

16. A method of forming multiple two level structures in a semiconductor substrate, the method comprising:

lithographically forming a pattern having structures of different widths, the structures extending up from a first floor of the substrate;

oxidizing the structures on the substrate until lines of structures of a selected width are substantially fully oxidized;

CHF_3 reactive ion etching the oxide to expose the first floor; and

selectively etching the first floor deeper into the substrate to form a second floor.

17. A method of forming a comb actuator in a semiconductor substrate, the method comprising:

forming pillars of alternating thick and thin widths extending from a first floor of the substrate;

oxidizing the wafer until pillars of thin width are substantially fully oxidized;

etching the oxide to expose the first floor;

etching the first floor deeper into the substrate to form a second floor; and releasing the comb actuator.

18. The method of claim 17 and further comprising removing the oxide and repeating oxidizing, etching and etching to form a further level of the multiple level structure.

19. The method of claim 17 and further comprising forming contacts to independently couple sources to the respective thin and thick lines.

20. The method of claim 17 wherein the thin and thick lines comprise comb fingers with a gap of between approximately 0.3 and 10 microns.

21. A method of forming two level structures in a semiconductor substrate, the method comprising:

forming lines of different widths having a first floor;

oxidizing the wafer until lines of thinner width are substantially fully oxidized;

etching the oxide to expose the first floor;

etching the exposed first floor deeper into the substrate to form a second floor; and

releasing the lines to form suspended structures.

22. The method of claim 21 wherein releasing the lines comprises:

oxidizing the lines; and

etching the substrate in all directions.

23. The method of claim 22 wherein etching the substrate in all directions comprises a SF_6 reactive ion etch.

24. A Z actuator supported by a substrate comprising:

a plurality of thin fingers;

a plurality of thick fingers interleaved with the thin fingers;

a torsional spring coupled to the thin fingers, wherein the thin fingers move in a z direction from the substrate when electrically driven.

25. The Z actuator of claim 24 wherein the thick fingers comprise a top and bottom level.

26. The Z actuator of claim 25 wherein the top and bottom levels are isolated by a section of thermal oxide.

27. The Z actuator of claim 24 wherein the thin fingers are released, and the thick fingers are partially undercut.

28. The Z actuator of claim 24 wherein the substrate is grounded.

29. The Z actuator of claim 24 and further comprising a bonding pad of large width compared to the fingers, and wherein the bonding pad contacts the substrate at two levels.

30. The Z actuator of claim 24 and further comprising a honeycomb bonding pad.

31. The Z actuator of claim 30 wherein the honeycomb is formed of intersecting lines of width substantially equal to the thick fingers, and further comprises a top and bottom level electrically isolated from each other.

32. The Z actuator of claim 31 wherein the thick fingers are connected to the honeycomb bonding pad, with a top level of the thick fingers connected to the top level of the bonding pad and a bottom level of the thick fingers is connected to the bottom level of the bonding pad.

33. A three level Z comb actuator supported by a substrate comprising:

a plurality of first fingers having an upper portion formed of oxide, and a conductive lower portion;

a plurality of second fingers interleaved with the first fingers, the second fingers having a top portion of oxide sandwiching a conductor, and a conductive bottom portion; and

a plurality of shadow fingers corresponding to the plurality of first and second fingers, the shadow fingers coupled to the plurality of first and second

fingers wherein the first fingers move in a z direction from the substrate when electrically driven.

34. The three level Z comb actuator of claim 33 wherein the second fingers are positively biased.

35. The three level Z comb actuator of claim 34 wherein the shadow fingers corresponding to the second fingers are grounded.

36. The three level Z comb actuator of claim 33 wherein the first fingers partially overlap the second fingers.

37. The three level Z comb actuator of claim 33 and further comprising a torsional spring coupled to the first fingers.

38. The three level Z comb actuator of claim 33 wherein the second fingers are electrically isolated from corresponding shadow fingers.

39. The three level Z comb actuator of claim 33 wherein the first fingers move in response to a force that is constant over the entire range of motion of the first fingers.

40. A multiple level Z comb actuator supported by a substrate comprising:

a plurality of released first fingers having an upper portion formed of oxide, and a conductive lower portion;

a plurality of second fingers interleaved with the first fingers, the second fingers having a top portion of oxide sandwiching a conductor, and a conductive bottom portion;

a mirror moveably coupled to the plurality of first fingers, and

a plurality of shadow fingers corresponding to the plurality of first and second fingers, the shadow fingers coupled to the plurality of first and second fingers wherein the first fingers move in a z direction from the substrate when electrically driven.

41. The multiple level Z comb actuator of claim 40 and further comprising an axis coupled to the first fingers and coupled to the mirror to move the mirror when the first fingers move with respect to the second fingers.

42. The multiple level Z comb actuator of claim 41 and further comprising a torsional spring coupled to the mirror, the spring being orthogonal to the axis.

42. The multiple level Z comb actuator of claim 41 and further comprising:

two sets of interleaved first and second fingers coupled to the axis on opposite sides of the mirror; and

a torsional spring coupled to the mirror, the spring being orthogonal to the axis.

43. The multiple level Z comb actuator of claim 42 wherein the axis comprises two portions, each extending to a set of first fingers from the mirror, and wherein the mirror rotates about the torsional spring.

44. An X,Y,Z comb actuator supported by a substrate comprising:

two first sets of opposed interleaved moveable and fixed fingers coupled by an axis and having a torsional spring orthogonally coupled to the axis to provide Z motion;

a first nested frame surrounding the two first sets of opposed interleaved moveable and fixed fingers, wherein such fixed fingers are coupled to the first nested frame;

two second sets of opposed interleaved moveable and fixed fingers;

a second nested frame, wherein the second nested frame is coupled to the first nested frame by a spring, and wherein the movable fingers of the second sets are coupled to the first nested frame, and the fixed fingers of the second sets are coupled to the second nested frame;

two second sets of opposed interleaved moveable and fixed fingers; and

a third frame surrounding the first and second nested frame, wherein the third frame is coupled to the second nested frame by a spring, and wherein the movable fingers of the third sets are coupled to the second nested frame, and the fixed fingers of the third sets are coupled to the third frame.